Q2 Known Good Substrates Technical Report
CONTRACT/PR NO. N00014-05-C-0324 Dow Corning Corporation
Quarterly Technical Report
Reporting Period: 2 March 2006 – 31 May 2006

Executive Summary

The first crystal growth quarter (1/15/06-4/15/06) was completed and the second growth quarter will finish 7/15/06.

In the first quarter over 30 crystal growths were performed. Key accomplishments and Pareto analysis show that the program is close to or on schedule for both 76 mm and 100 mm crystal and wafer development by PVT. The development of 76 mm crystals by vapor is about 1-2 months behind schedule due to equipment vendor delays. Micropipe performance median was 50/cm^2 range with only 3 boules approaching 30/cm^2, behind median targets of 30/cm^2. Similarly, areal defect density is also above target goals. Assessment of bulk impurity (metals B, P, Ti, V, Fe) shows significant improvement from 2004-5 timeframe and is at program targets (5E15 atoms/cm^3 range) and also equal to or better than results published by major competitors. Resistivity control in n+ wafers demonstrated ~4% one sigma nonuniformity, on par with competitors.

Polishing capability is producing of 76mm wafers with high control of wafer shape TTV<5 um and Bow +/-5 um – state of the art flatness performance. Epitaxy does not degrade this performance.

Developmental epitaxy work in the multiwafer system is meeting doping and uniformity targets, but surface defectivity jumped at the end of the quarter. A key finding is the carrier lifetimes measured on chlorosilane epitaxy by microwave photoconductive decay are exceeding the 10 us level. Q1 Deliverable wafers and epiwafers were shipped to ONR, NRL, USC, NGES and Dow Corning for evaluations and device fabrication. All wafer shipments included thorough wafer map analysis data (shape, micropipes, LLS defects, uniformity, resistivity, and where appropriate, carrier lifetime maps.)

Technical Progress

The following table documents the key program thrusts, milestones by quarter and progress for the activity in the quarter documented by this report.

Thrust	Complete by Quarter	Milestone	Progress
Task 1: SiC Wafer Products	**1**	50% sliced wafer increase for 76 mm diameter crystals	Since Jan 2005 (the anticipated start of the KGS program, about which the goal was projected) the slice wafer yield has increased by 2x.
	2	Complete model of 100 mm PVT growth	Thorough modeling of 76mm was extended one month to insure agreement with all experimental results. 100 mm modeling is underway at both subcontractor and in house. Initial modeling of the heat losses has helped to

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14. ABSTRACT

The Known Good Substrates (KGS) program is on track technically and financially with program tasks. Q1 wafer fabrication was completed, Q1 metrology and characterization was completed, and wafers were distributed to partners. All but 1 subcontract is in place and many subcontractors are ramping up activities with wafers coming out of the Q1 wafer fabrication.

15. SUBJECT TERMS
SiC wafer, SiC epi, SiC material metrology

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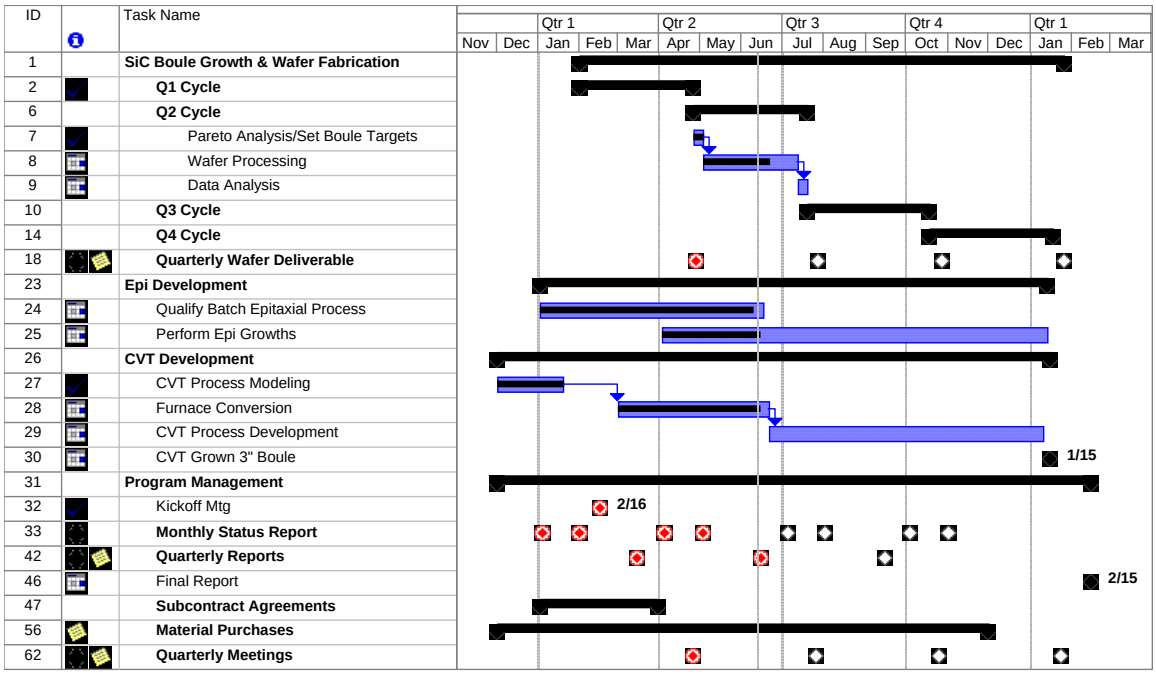
			drive PVT process alterations which resulted in a 3x reduction of growth rate variability in 100 mm PVT processes.
	3	80% sliced wafer increase for 76 mm diameter crystals	Since Jan 2005 (the anticipated start of the KGS program, about which the goal was projected) the slice wafer yield has increased by 2x.
	4	Deliver first generation 4H n+ 100mm wafers	Q2 work is now generating first groups of PVT crystals for wafer slicing. 100 mm quality is limited by spurious edge defects of 5mm or less. MPD<80/cm2. Crystal expansion continues to produce larger crystals and eliminate edge defects.
Task 2: Materials Applied Research	**1**	Complete model of Generation 1 bulk gas growth	Due to delay in release of funds for KGS, Dow Corning funds were used to initiate the modeling project in the second half of 2005. A Gen-1 model has been completed based on one chlorosilane precursor and one set of process conditions. The results show that growth rate and deposition uniformity comparable to PVT processes can be expected over the temperature range 1900-2100 C. At this point it is believed largest source of error in the model is the formation of deposits on ancillary surfaces of the crucible.
	1	Qualify Batch Epitaxy processes for program	Recent epitaxy work focused to develop processes for the Northrup Grumman device subcontract. Developmental work in the multiwafer reactor produced mid doped (1E15-1E16/cm^3) epi layers with thickness uniformity (standard deviation/mean) of less than 4 % and doping uniformity of less than 8%. By the end of Q2 24 epiwafers will be processed and delivered to Northrup for device fabrication. Limited work was performed to assess low doped drift layer epitaxy. In these cases it was demonstrated that levels of 5E14/cm^3 could be produced in the multiwafer reactor. Epiwafer deliverables were shipped to NRL with full characterization data. Samples exhibit carrier lifetimes in the 5-10 usec range. For the remainder of the first year of the KGS program, the minimum doping target for drift layer epitaxy will stay in the 1-3E15/cm^3 range to afford better assessment of carrier lifetime by microwave photoconductive decay measurement
	2	Demonstration of CVT growth	CVT (gas phase) depositions start week of 6/12/06. System is in house and facilitized.

	4	Deliver first 76mm CVT wafers	
Task 3: Metrology for Wafer Specifications	**2**	Implement LLS inspection with particles, pits, and scratches delineated.	Wafers were shipped to ONR and NRL with LLS topography maps. First generation work to segregate defect types is nearly complete and data will be provided in June.
	3	Start routine microwave loss inspection of 4H SI wafers	Loss measurement calibration and test is progressing well. Full wafer global loss testing in cavities has been performed at 4 GHz and compared to SI GaAs as a benchmark-Several 6H SI wafers with resistivity 1E5-1E7 ohm cm show microwave loss equal to SI GaAs. There is no obvious correlation between loss and resistivity, as expected in these materials. Mapping tests show many regions with loss less than SI GaAs. Next focus is on extending the measurements to X-band.
	2	u-PCD tool installed and lifetime measurements implemented for epitaxy layers and SI wafers	u-PCD testing of carrier lifetime is fully operational. Key results show that chlorosilane-based SiC epi has very high lifetime. Samples were delivered to NRL for conformational analysis.
Task 4: Device Technology Maturation	**1**	Publish Rev-0 roadmap for wafer and epi goals	See Appendix 2
	2	Complete disposition strategy for n+ epiwafers	See Appendix 3.
	4	Publish revised roadmap to reflect power and RF device progress	

Schedule

A detailed description of achievements and progress against milestones and deliverables was provided in the table above. The project schedule is provided below as an overview of the progress against the high level tasks on the program. Progress is on track with exception of the gas phase (CVT) task, which is 1.5 months behind due to delays at the tool vendor (the schedule has been update accordingly). It is expected that this can be made up in subsequent months.



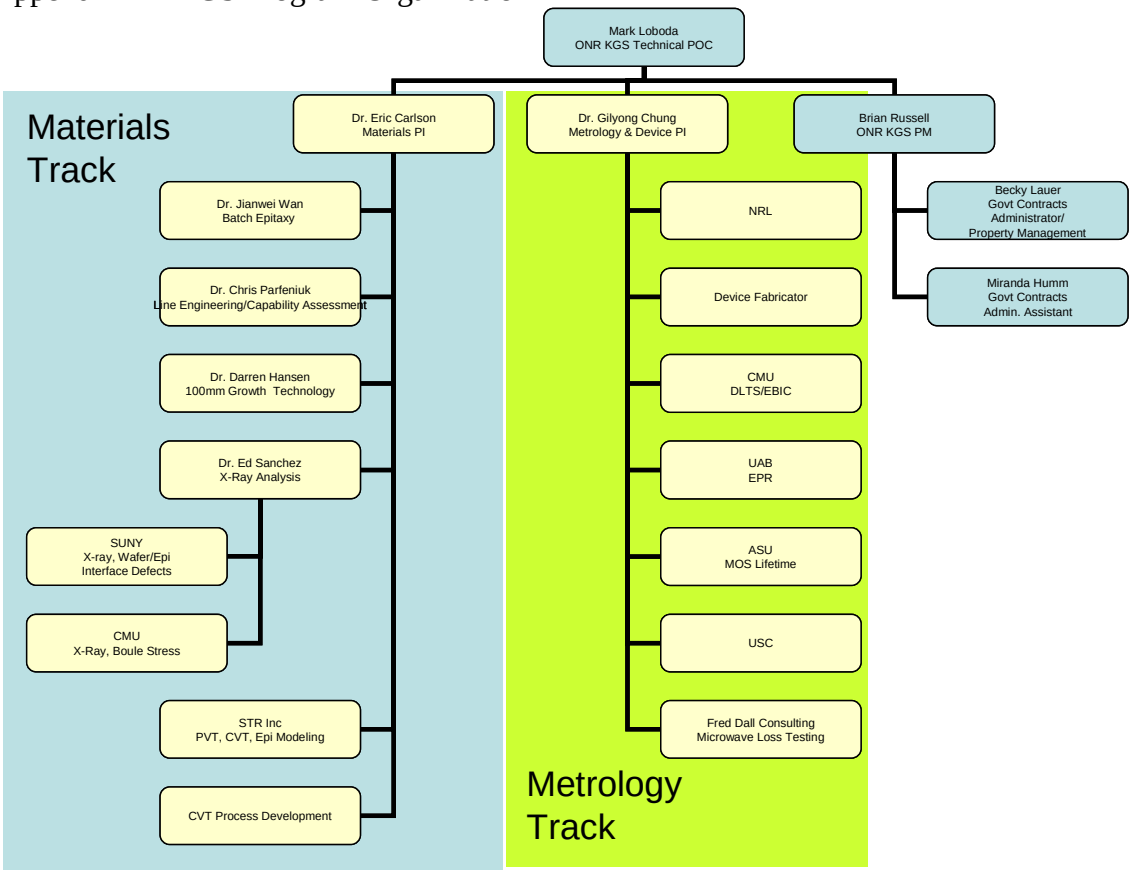
Program Management

Monthly e-mail status updates were submitted for March, April, and May to the Program Officer, Dr. Colin Wood. The face to face (all participants) program review meeting that was planned for July has been moved to October to allow for a better review of more program activities. An interim review with Dr. Colin Wood will still be held in the July or August timeframe. All subcontract agreements have completed negotiations with the last two planned for signature in early June. Appendix 3 contains the updated distribution of program wafers. It is important to note that the original plan had to be modified to meet various needs and opportunities for the work on the program – see Appendix 3 for details.

Cost Status

A Q2 cost status update was provided to Dr. Colin Wood in the June e-mail monthly update.

Appendix 1 – KGS Program Organization



Appendix 2 – KGS Rev-0 Roadmap for Wafer and Epi Goals

Proposed Goals:	Top 30%	Top 50%
Timing for 76 mm diameter	Q1/06	
Timing for 100 mm diameter	Q1/07	
MPD and inclusions (cm^{-2})	<10	<30
Scratches (total length)	<50% diameter	<75% diameter
Areal density surface particles and pits in epiwafers, diameter >0.5 um	<5 cm^{-2}	<10 cm^{-2}
Bulk Metals Contamination B, Al, Ti, V, Fe ($atoms/cm^3$)	<1E15	<5E15
Stable Epi drift layer carrier concentration ($atoms/cm^3$)	<1E14	<5E14
Epi thickness uniformity	<8%	<10%
Epi Doping Uniformity	<10%	<15%

Appendix 3 – KGS Wafer Disposition Plan

Wafers Produced for Program	Q1	Q2	Q3	Q4	Total Wafers
75mm n+	0	43	21	28	92
75mm SI	0	0	6	8	14
100mm n+	0	0	3	4	7
100mm SI	0	0	0	2	2
Total	0	43	30	42	**115**

	Epi	No Epi	Epi	No Epi	Epi	No Epi	Epi	No Epi	total epi Wafers	Epi Growths
Internal 3" Epi n+			37	6	21		26	2	84	16.8
Internal 3" Epi SI						6		8	0	0
Internal 4" Epi n+						3	2	2	2	2
Internal 4" Epi SI								2	0	0

Distribution	Epi	No Epi	Epi	No Epi	Epi	No Epi	Epi	No Epi	
NRL (Lifetime Measurements)			5		2	2	4	2	15
CMU (Deep Level, XRT)					2	2	2	3	9
Alabama (Deep Level Measurements)						2		3	5
ASU (Lifetime Measurements)					2		2		4
USC (Diodes)			2		1		1		4
NGES			28		14		14		56
ONR			2	6		3	5	6	22
									115

Mixed Lots
n+
SI

The plan is slightly altered from that in the original proposal. No cost changes result. The number of wafers increases. Changes are primarily a result of the Northrup Grumman subcontract which required more n+ wafers than originally proposed. To accommodate this less semi-insulating material will be produced. DCCS has already started to send in deliverables shown in the Q2 part of the plan. Additional wafers were sent to University of Alabama, Arizona State and CMU at no cost to the program.